

WHAT IS CLAIMED IS:

- 1                   1.     A plasma processing apparatus comprising:  
2                   a single carrier source adapted to generate a first RF signal at a carrier  
3 frequency;  
4                   a modulation source adapted to generate a second RF signal at a  
5 modulation frequency;  
6                   a modulator adapted to modulate the first RF signal with the second RF  
7 signal to form an amplitude modulated signal, wherein the amplitude modulated signal  
8 contains peaks with amplitudes greater than or less than amplitudes of the peaks of the  
9 first RF signal; and  
10                  a plasma processing chamber coupled to the modulator.
- 1                   2.     The apparatus of claim 1 further comprising:  
2                   a power amplifier adapted to amplify the amplitude modulated signal from  
3 the modulator to generate a high power amplitude modulated signal.
- 1                   3.     The apparatus of claim 1 further comprising:  
2                   a transmission line for transmitting the amplitude modulated signal; and  
3                   a single impedance matching network, wherein the single matching  
4 network is adapted to receive the amplitude modulated signal and provides impedance  
5 matching from the transmission line to the plasma. *A*
- 1                   4.     The apparatus of claim 1 wherein the modulation source is further  
2 adapted to generate a third frequency modulating RF signal, and the modulator is further  
3 adapted to modulate the first RF signal with the second RF signal and the third RF signal  
4 to form an amplitude and frequency modulated signal.
- 1                   5.     The apparatus of claim 1 wherein the second RF signal is in the  
2 form of a sine wave.
- 1                   6.     The apparatus of claim 1 wherein the apparatus is an etching  
2 apparatus.
- 1                   7.     A plasma processing apparatus comprising:

2 a carrier source adapted to generate a first RF signal at a carrier frequency;  
 3 a modulation source adapted to generate a second RF signal at a  
 4 modulation frequency;  
 5 a modulator adapted to modulate the first RF signal with the second RF  
 6 signal to form a frequency modulated signal; and  
 7 a plasma processing chamber coupled to the modulator.

1 8. The apparatus of claim 7 further comprising:  
 2 an amplifier adapted to amplify the frequency modulated signal to generate  
 3 a high power frequency modulated signal.

1 9. The apparatus of claim 7 further comprising:  
 2 a transmission line for transmitting the frequency modulated signal; and  
 3 a single matching network adapted to receive the frequency modulated  
 4 signal to provide impedance matching from the transmission line to a plasma.

1 10. The apparatus of claim 7 wherein the modulation source is further  
 2 adapted to generate a third RF signal at an amplitude modulation frequency, and wherein  
 3 the modulator is further adapted to modulate the first RF signal with the second RF signal  
 4 and the third RF signal to form an frequency and amplitude modulated signal.

1 11. The apparatus of claim 7 wherein the second RF signal is in the  
 2 form of a sine wave.

1 12. The apparatus of claim 7 wherein the apparatus is an etching  
 2 apparatus.

1 13. The apparatus of claim 7 wherein the modulation frequency is less  
 2 than about 0.1 times the carrier frequency.

1 14. A method of delivering power to a plasma processing chamber, the  
 2 method comprising:  
 3 generating a first RF signal at a carrier frequency;  
 4 generating a second RF signal at a modulating frequency;

5 forming an amplitude modulated signal by modulating the first RF signal  
6 with the second RF signal, wherein the amplitude modulated signal contains peaks with  
7 amplitudes greater than or less than amplitudes of peaks of the first RF signal; and  
8 delivering only the amplitude modulated signal to a reactant gas within the  
9 plasma processing chamber to form a plasma.


1 15. The method of claim 14 further comprising, prior to generating the  
2 plasma:

3 amplifying the amplitude modulated signal to form a high power  
4 amplitude modulated power signal, and wherein  
5 delivering plasma within the plasma processing chamber using the  
6 amplitude modulated signal comprises using the high power amplitude modulated signal  
7 to generate the plasma.

1 16. The method of claim 14 wherein the second RF signal has a lower  
2 frequency than the first RF signal.

1 17. The method of claim 14 wherein forming an amplitude modulated  
2 signal comprises:  
3 forming an amplitude and frequency modulated RF signal with the second  
4 RF signal and a third frequency modulating RF signal.

1 18. The method of claim 14 further comprising:  
2 modifying the amplitude modulated signal by adjusting a modulation  
3 index.

1 19. The method of claim 14 wherein the second RF signal comprises a  
2 signal of form  $\beta \sin(\omega_m t)$ , wherein  $\beta$  is a modulation index and is less than or equal to 1,  
3  $\omega_m$  is the modulating frequency, and  $t$  is time. 

1 20. The method of claim 14 wherein the amplitude modulated signal is  
2 of the form  $E_0[1 + \beta \sin(\omega_m t)] \sin(\omega_c t)$  wherein  $\beta$  is a modulation index,  $\omega_m$  is the  
3 modulating frequency,  $\omega_c$  is the modulation,  $E_0$  is an initial electric field, and  $t$  is time.

1 21. The method of claim 14 further comprising passing the amplitude  
2 modulated signal through an impedance matching network.

1 22. The method of claim 14 wherein second RF signal is in the form of  
2 a sine wave.

1 23. A method of delivering radio frequency (RF) power to a plasma,  
2 the method comprising:  
3 generating a first RF signal at a carrier frequency;  
4 generating a second RF signal at a modulation frequency;  
5 forming a frequency modulated signal by modulating the first RF signal  
6 with the second RF signal; and  
7 generating a plasma within the plasma processing chamber using the  
8 frequency modulated signal.

1 24. The method of claim 23 further comprising:  
2 amplifying the frequency modulated signal to generate a frequency  
3 modulated power signal, and  
4 wherein generating a plasma comprises using the frequency modulated  
5 power signal to generate a plasma.

1 25. The method of claim 23 wherein forming the frequency modulated  
2 signal comprises:  
3 forming a frequency and amplitude modulated signal by modulating the  
4 first RF signal with the second RF signal, and a third amplitude modulating signal.

1 26. The method of claim 23 wherein the modulation frequency is less  
2 than about 0.1 times the carrier frequency.

1 27. The method of claim 23 wherein the frequency modulated power  
2 signal is of the form  $E(\omega_c, t) = E_0[\exp(i\omega_c t)] \exp[i\beta \sin(\omega_m t)]$ . A

1 28. The method of claim 23 wherein the carrier frequency is 13.56  
2 MHz.

1 29. The method of claim 23 further comprising passing the frequency  
2 modulated signal through an impedance matching network.

1 30. The method of claim 23 wherein the second RF signal is in the  
2 form of a sine wave.

1 31. A power system for a plasma processing apparatus, the power  
2 system comprising:  
3 a single carrier source adapted to generate a first RF signal at a carrier  
4 frequency;  
5 a modulation source adapted to generate a second RF signal at a  
6 modulation frequency; and  
7 a modulator adapted to modulate the first RF signal with the second RF  
8 signal to form an amplitude modulated signal, wherein the amplitude modulated signal  
9 contains peaks with amplitudes greater than or less than amplitudes of the peaks of the  
10 first RF signal.

1 32. A power system for a plasma processing apparatus, the power  
2 system comprising:  
3 a carrier source adapted to generate a first RF signal at a carrier frequency;  
4 a modulation source adapted to generate a second RF signal at a  
5 modulation frequency; and  
6 a modulator adapted to modulate the first RF signal with the second RF  
7 signal to form a frequency modulated signal.

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